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Kapteyn Astronomical Institute & Scientific Visualization and Computer Graphics SCVG

Big Data Analysis in Astronomy

Visual Analytics for High-Dimensional Astronomical Data Using Gradient Clustering in Dimensionality Reduction

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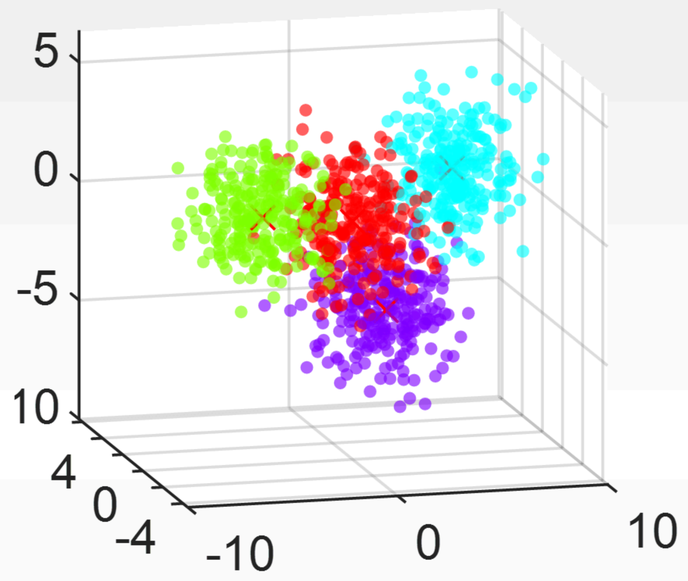
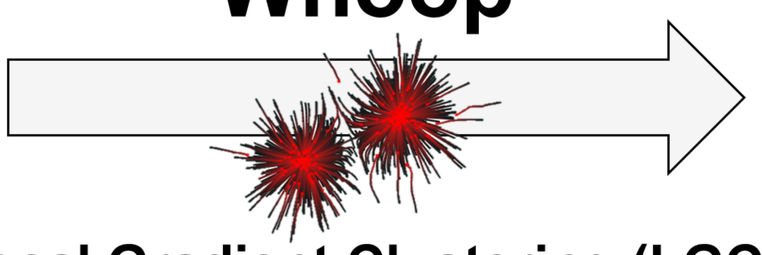
Original Data



Gaussian random data with four clusters in N-D

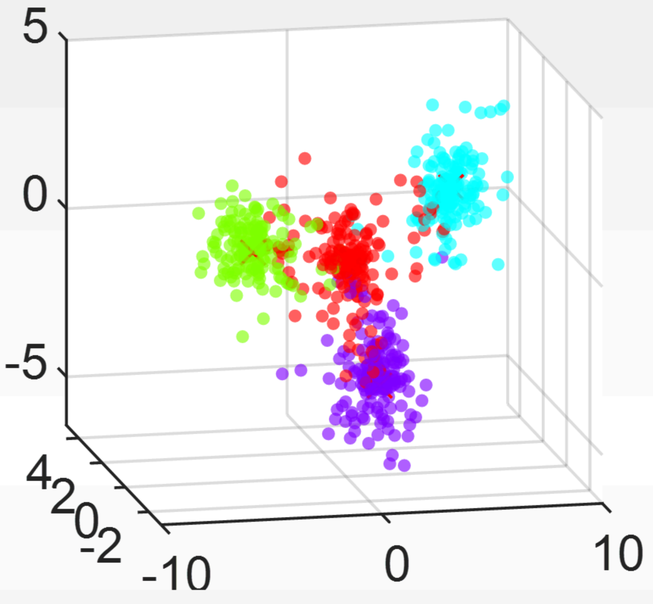
Preprocess high-dimensional data "Whoop"



Local Gradient Clustering (LGC)

Shift points along the gradient of the kernel density estimator

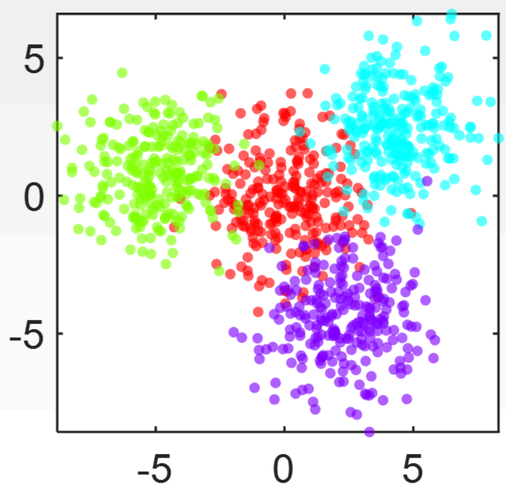
Preprocessed Data



Clusters are separated in N-D

Dimensionality Reduction

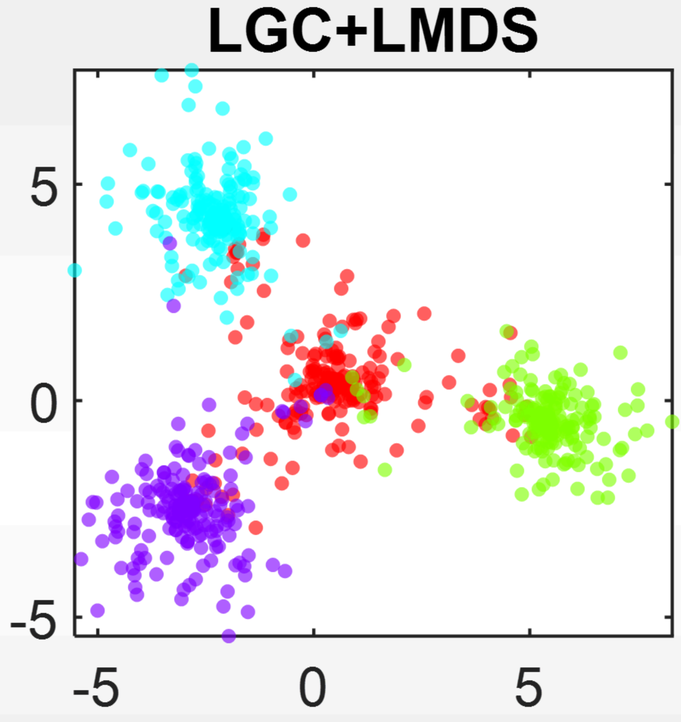
LGC+LMDS



Clusters are not well separated in the 2D projection

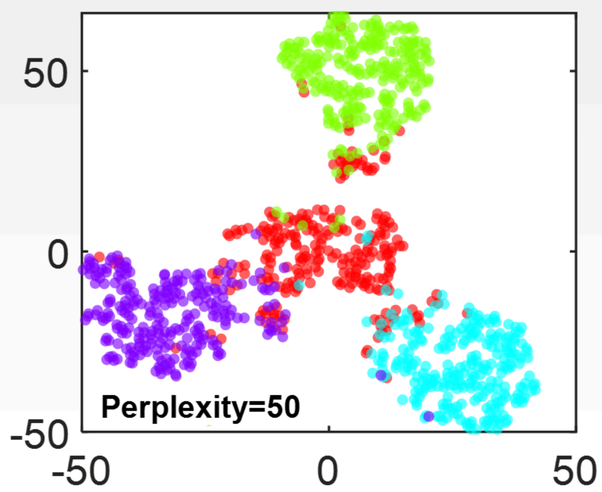
Landmark Multidimensional Scaling (LMDS) [1]

VS.



Clusters are well separated in the 2D projection

VS.

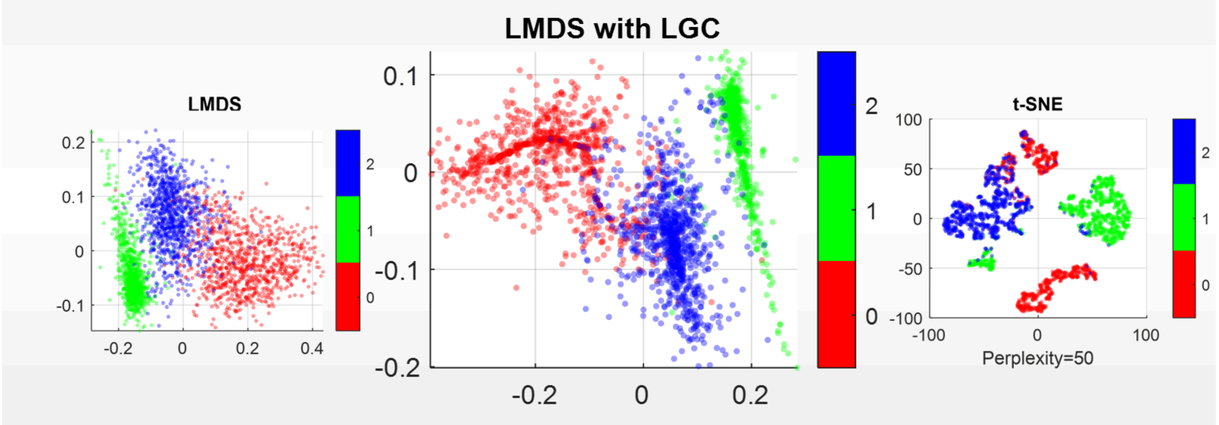


Clusters are well separated in the 2D projection

t-Stochastic Neighbor Embedding (t-SNE) [2]

Apply to MNIST Dataset

- First three digits (0, 1, and 2) of the MNIST dataset [3]
  - Two Vertical/horizontal gradient histogram features
  - Three Mean-centered pixel coordinate features



References

[1] V. De Silva and J. B. Tenenbaum, "Sparse multidimensional scaling using landmark points," Technical report, Stanford University, Vol. 120, 2004.
[2] L. V. D. Maaten and G. Hinton, "Visualizing data using t-SNE," Journal of machine learning research, No. 9, pp. 2579-2605, 2008.
[3] Y. LeCun, L. Bottou, Y. Bengio, and P. Haffner, "Gradient-based learning applied to document recognition," Proceedings of the IEEE, Vol. 86, pp. 2278–2324, 1998.
[4] M. Muja and D. G. Lowe, "Fast Approximate Nearest Neighbors with Automatic Algorithm Configuration", International Conference on Computer Vision Theory and Applications (VISAPP'09), 2009.
[5] V. A. Epanechnikov, "Non-parametric estimation of a multivariate probability density," Theory of Probability and its Applications, Vol. 14, No.1, pp. 153-158, 1969.
[6] K. Fukunaga and L. Hostetler, "The estimation of the gradient of a density function, with applications in pattern recognition," IEEE Transactions on information theory, Vol. 21, No. 1, pp. 32-40, 1975.

Summary

Preprocess high-dimensional data so that potential clusters are well separated after dimensionality reduction

Method

I. Generate a kernel density estimator with an Epanechnikov kernel and use only the neighbors when computing the density [4-5]
II. Shift points along the gradient of the kernel density estimator as in gradient ascent → points moving towards the center → contraction [6]
III. Perform LMDS [1]

Cluster Separation & Scalability & Predictability

- Clusters are well separated after the projection by preprocessing the data with local-based gradient clustering
- More computationally scalable than t-SNE, in terms of wall-clock time
- Predictable outcome with three parameters

Future Work

- Apply to astronomical surveys such as GAIA DR2 and GALAH DR2 to find underlying patterns in the data

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